HIGH CAPACITY WASTE-TO-ENERGY CONVERSION
AT THE KIEL DISTRICT HEATING STATION

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This is an extremely interesting paper since it provides excellent statistical data in the operation of a incinerator. Although the plant is relatively small, many of the values can be extrapolated to larger size plants. Some specific comments are as follows:

1. Operation of the Kiel District Heating Station is typical of European practice. The city is the sponsor for waste collection, transportation and disposal and the city also owns the municipal power company which supplies electricity, water and district heat. With that arrangement, it is relatively simple for a solid waste plant to be organized and operated. In contrast, U. S. cities in some cases operate their own solid waste collection system, but in many cities it is done by private companies. Also, in most cases cities do not own the utilities that in most cases are privately held companies. With the arrangement normally found in the U. S., it is much more difficult to come to a final agreement in the conception and operation of a solid waste plant.

2. It is ideal for a utility to operate the solid waste plant such as happened in Kiel. In the U. S. this is usually not possible and in most cases utilities are reluctant to even accept the energy produced by solid waste plants.

3. The plant is relatively small by modern U. S. standards. The initial installation was two lines each of 5.5 t/hr or approximately 264 t/day maximum. Phase two was twice as big but still quite small compared to U. S. plants of the last few years, which have gone to well over 1000 t/day.

4. Investment cost seems to be on the high side. For the initial installation (264 t/day) and the reported cost of 14 million dollars, it works out to $53,000/t which is about the same cost as a similar plant in the U. S., Hampton, Virginia, reporting $51,500/t. The difference is that Hampton was built in 1980 and Kiel was built in 1975. The reason could be the sophisticated scrubbing system for air pollution control that accounts for a large part of the original investment.

5. The installation itself appears to be typical of small mass burning installation except for the addition of a Venturi type wet scrubber after the electrostatic precipitator.

6. Utilization of low pressure for district heating is quite common in Europe and its use is ideal for mass burning installations with large variations of pressure and temperature would not be permissible in a plant generating electricity.

7. If we consider the two lines of 5.5 t of refuse per hour and one line of 11 t/hr we have a maximum of 528 t/day. On a per year basis it means 182,000 t at 100 percent full capacity. The figures given indicate that the plant ran at less than 50 percent capacity for many years and even in 1981 it operated at only 68 percent
capability. This means that the amount of down time available for maintenance was quite large during the years that the plant has been in operation.

8. The residue generation rate appears to be on the high side at over 0.4. It indicates a reduction in weight of less than 60 percent. Most U. S. mass generation plants are obtaining values in the order of 75 percent reduction and resource recovery facilities an even higher value.

9. The yearly budget indicates a remarkable consistency year after year. Over a 5-year period both expenditures and revenues have increased in the order of less than 8 percent which is exceptionally low. Tipping fee is basically the same that it was 5 years ago, again a remarkable accomplishment.

10. It is to be noted that of the largest expenditures, Capital Service is only in the order of $13/t or about 37 percent of total expenditures. This is, of course, due to the low interest at the time of construction. Any such plant built today would have a debt service of probably more than double the amount indicated.

11. It is to be noted that the tipping fee at over $25/t for the last 5 years is extremely high compared to present day U. S. values. In most U. S. locations the tipping fee at the present time is below $20/t. American cities are reluctant to pay higher values and this is probably the reason for the difficulties in financing new plants.

12. Probably the most interesting item in the whole paper is the installation of a wet scrubber after the precipitator. This installation greatly reduces the particulates emission.

Most U. S. installations presently have a maximum value of 0.06 gr/SCF. The values given for the plant are approximately 50 percent higher after the precipitator but in the order of only 0.01 after the wet scrubber. This is an exceptionally low value that is usually not required in the U. S.

13. It should be noted that the height of the stack is 354 ft, much higher than most stacks in the U. S. The Capital Cost of the Facility was undoubtedly influenced by the size of this stack.

14. The high operating cost of the scrubbing system makes questionable the convenience of its installation. There is no question of the advantage of added emission reduction; however, an operating cost of over $5/t just for the scrubber appears to be on the high side. In view of the present economics of plant installations, it is doubtful whether such a system could be justified in the U. S.

**Discussion by**

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This is one of the most useful papers ever presented on waste-to-energy systems. In careful detail it gives the performance and cost data which do indeed describe a very successful, environmentally clean operation along with description of the problems of acid gas scrubbing and their eventual solution.

One aspect that, in such a long and detailed paper, received insufficient emphasis, was that the decision not to cogenerate, which, while well justified, does result in energy waste during June, July, and August. And, incidentally, that decision to produce low pressure, low temperature steam has undoubtedly been a major factor in permitting extensive overloading and high utilization compared to the practice in most high temperature plants which, at the present state of the art, usually have one boiler idle as a reserve in case of working boiler outage. As shown in Table 6, this is a high-cost plant, but it would be even higher in operating cost if it were cogenerating. However, as the cost of precious, irreplaceable fossil fuels continues to rise, most waste-to-energy plants must become cogenerating.

The ambient air monitoring results, with and without the chloride-removal scrubber in operation, show, for the first time, that scrubbers are of dubious need. This is true especially for a seacoast location where seaspray causes chlorides to be a normal component of the atmosphere, even one or two kilometers inland.

The switch from conveyor to piston-type residue removal is another recent instance of acceptance of a successful design innovation that began many years ago in Bavaria.

I am glad for this opportunity to again thank the Kiel plant staff engineer who cordially conducted me through the Kiel Plant on October 7, 1977, and, in good English, answered my many questions on this unique plant located in the very midst of an attractive residential area.
This paper describes a facility of which the planners and the City of Kiel can be justly proud.

There are several points made which I have repeatedly made to the continuing stream of visitors to Nashville. These are:

1. The facility is a Power Plant; it should be designed and operated by power experienced personnel.

2. The Plant, and all such plants, are primarily "Hardware" Plants versus "Technology" Plants.

The paper should be must reading for any city planner. It is interesting to note that, even with a good track record, Kiel has had some costly and serious problems. This confirms a long-held view that these plants demand a continuing engineering effort, and a high level of professional and technical competence in operative management.

AUTHORS' REPLY

To S. E. Martinez

Sizing of the Kiel RRF was determined by the needs of this particular city. With an installed capacity of 530 STPD7, Kiel falls into the small-to-medium sized facility range, which should be of special interest to the U. S. market. Two recent surveys, one by the NCRR (National Center for Resource Recovery) and AISI (American Iron and Steel Institute) clearly indicate a strong upward trend in this size range, (see Ref [1,2]). Of some 70 resource recovery projects listed, 42, or 60 percent, are in the below 600 STPD7 size range. Examples of U. S. plants in this range besides Hampton are Auburn, Braintree, Gallatin, Glen Cove, Norfolk, Pittsfield, etc.

As far as investment costs are concerned, any comparison with other facilities, especially with U. S. facilities, must take into account a number of circumstances which are unique to Kiel and West Germany. For example, Kiel is an inner city plant located on a knoll and surrounded by residential housing. Hampton, Virginia, on the other hand, is located far away from residential areas on a level wooded plot. Moreover, some of the German standards for environmental protection are more stringent. As a result, Kiel features a number of cost-sensitive provisions which do not apply to Hampton: flue gas scrubbing system with re-heating, tall stacks, careful sound suppression, oil-fired standby boilers, etc. The authors believe that once the appropriate deductions are made, cost differences will be negligible.

The comments made with regard to plant capacity missed the point that during the first 5 years of operation, installed plant capacity was only 96,400 STPY and not 192,700 STPY. The latter capacity was reached during 1980 when the plant was expanded as part of Phase II construction. Inspection of Table 2 in the paper reveals that during the first 5 years Kiel reached, or even exceeded, annual capacity. (See the column labeled “Refuse Disposal in STPY”.) Since all boiler equipment requires some downtime for maintenance and annual inspection, this Kiel accomplishment was only made possible by the rugged nature of the grate system which permitted overloading. This point can be best illustrated by referring to the “Annual Load Factors” in Table 4. These LFG’s showed overloads ranging from 10 percent to 45 percent for all operating years. “Equipment Utilization” peaked during 1979 and declined thereafter, mostly due to construction activities and shortages of refuse. “Equipment Utilization” is expected to increase again in the future as additional supplies of refuse are secured. Negotiations with neighboring communities are already underway in order to obtain additional refuse supply commitments. Thus the prospects for continued improvement in “Equipment Utilization” are judged to be excellent.

When comparing residue generation rates between mass burning facilities in Germany and the U. S., consideration should be given to the following facts: First, the composition of U. S. refuse is generally more favorable to combustion because the ratio of combustibles to inerts is higher. This is largely a consequence of a higher paper content. Second, contemporary U. S. plants rarely contain wet scrubbers whose sludge must be disposed of in addition to grate and precipitator ash. In Kiel this sludge is added to the regular ash and taken off the premises by a private contractor who processes this mixture for use in the construction industry. After screening into two size fractions, the processed materials are used for subsurface construction purposes. As a result, very little landfill space is required for disposal of the ultimate rejects. (See also footnote 10 to Table 3.)

From the viewpoint of environmental protection, it is probably more important to judge the degree of burn-out achieved. Kiel’s operating permit allows a maximum concentration of 0.2 percent by weight in putrescibles. The TüV (National Testing Service) performed measurements at Kiel when the equipment was running at maximum load. These measurements resulted in a putrescible concentration of only 0.1 percent by weight. It is
difficult to conceive of a mass burner with a higher degree of burn-out.

The stack height was fixed in accordance with the original Phase I permit which already addressed the air quality requirement which the full sized or final plant would have to meet. Because of the newness of the scrubber technology, this permit allowed for occasional bypassing, provided that conditions varied from project to project. In order to comply, a relatively tall stack had to be installed. However, in the period between Phase I and Phase II construction, the environmental regulations were revised to the extent that scrubber bypassing is no longer permitted. This new demand was written into the Phase II permit.

Since the older scrubber equipment was responsible for a substantial portion of system downtime, a special effort was made to design new and more dependable scrubber equipment. Table 8 "General Scrubber Operating Data" clearly shows a much improved system performance, a trend which, according to more recent reports, continued into the present year.

Because the scrubbers now always operate in unison with the rest of the air pollution control equipment, including the tall stack, the authors consider any atmospheric contamination caused by emissions from the Kiel RRF as negligible.

With regard to scrubber costs, the licensing board did not include estimates of cost effectiveness in its evaluations. In West Germany the law is quite clear: without provisions for flue gas scrubbing a permit will not be granted.

To R. B. Engdahl

The decision not to cogenerate merits a separate and in-depth discussion which would go beyond the scope of this paper. Nevertheless, the authors wish to summarize several of the more salient points which led to this decision:

1. The Kiel RRF was designed to provide essential services only for a relatively small population, i.e., approximately 270,000 people. The specific investment costs for small electrical power generation equipment are known to be considerable. Furthermore, because of the difficult nature of refuse as a fuel, waste-derived cogeneration can only support base loads which inherently do not qualify for a premium in revenues.

2. The Municipal Power Company in Kiel already had an excess in generating capacity from its own plants as well as from its participation in a joint venture with Nordwestdeutsche Kraftwerke A.G. The latter is a large, regional generating plant and Kiel would also share in its future expansion. Thus any additional, small scale electrical generating capacity was not needed.

3. Kiel uses a great deal of coal as primary energy for electrical power generation and district heating. During 1980, for example, coal accounted for 70.4 percent, gas for 17.4 percent, refuse for 7.1 percent and fuel oil for 5.1 percent of total energy input. Due to its location as a major seaport, Kiel buys coal the world over under highly competitive pricing conditions. By comparison, refuse is a fuel which is more difficult and less efficient to process and, as a result, a small refuse-fired cogenerator is not cost effective.

4. The primary responsibility of the Kiel RRF is still the disposal aspect of refuse. Since landfill space is no longer available, such disposal service must be extremely dependable. This objective would clash, however, with the needs of electrical power generation which call for boilers with high operating temperatures and pressures. Unfortunately, refuse-fired boiler systems are prone to corrosion problems which are significantly influenced by the choice of steam conditions.

Kiel opted to generate refuse at rather low conditions of temperature and pressure which are more amenable to district heating than electrical power generation. The operating statistics documented in the paper indicate high equipment operating times and a substantial overload capacity. In effect, the plant's operating experience confirmed the wisdom of the original design decisions made.

5. The Kiel DHN is of sufficient size to accommodate, on annual basis, better than 90 percent of the thermal output available from the RRF. While any energy waste is regrettable, the loss of a relatively small amount during the summer seems to be a small price to pay for a large gain in equipment reliability.

With regard to air pollution control, the authors agree that flue gas scrubbing is of little use, when one takes into consideration the ambient air quality testing performed up to date and the particular Kiel conditions. However, West German law requires the installation and operation of scrubbing equipment. The specifics were written into the permit by the licensing board and, consequently, Kiel complied.

This statement cannot be universally applied, since conditions vary from project to project. In
fact, there are indications that the German EPA is working on a revision of TA Luft 74 which will set forth even tougher and/or additional requirements.

To M. E. Kirkpatrick

The Kiel waste-to-energy conversion project was constructed in two phases; each differed in the type of contracting approach used. During Phase I, the technology vendor, VKW, was awarded a turnkey type of contract. This did not prevent the Municipal Power Company from applying its long-term experience as power plant planners and operators by participating in major design and construction reviews.

Plant expansion, or Phase II construction, followed approximately 5 years later, thus allowing the Power Company to gather several years of operating experience within the specific context of Kiel’s needs. In order to make maximum use of this experience, it was decided that the Power Company would do the engineering and construction supervision directly.

As the paper points out, many difficulties and operating problems were avoided by this change in contracting. For example, Table 4 shows a high degree of equipment operating time immediately after start-up for the newest processing line. The authors feel that the active participation of a seasoned operator is essential to the planning of successful waste-to-energy projects.

Personnel selection and training are other critical requirements. The authors are in full agreement that qualified power plant operators are the best resource to draw on. At Kiel, the Power Company was fortunate in being able to assemble a new team which included senior members who were already involved with the ongoing operation of power plants and district heating stations elsewhere within the Power Company’s extensive network. In addition, a provision was made for specialized training including temporary assignments to similar facilities operated by other municipalities. In this context, it is interesting to note that several of the West German plants including Kiel also hired power engineers with prior shipboard experience in the merchant marine.